MODIS Solar Diffuser Stability Monitor Sun View Modeling

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***Abstract*—The Moderate Resolution Imaging Spectroradiometer (MODIS) reflective solar bands (RSBs) are calibrated on-orbit using an onboard solar diffuser (SD) panel, made of Spectralon. An onboard Solar Diffuser Stability Monitor (SDSM) tracks the SDs degradation. The SDSM views the sun through a 1.44% attenuation screen during SD calibration. The observed SDSM sun view response has shown serious unexpected ripples that are as large as 10% of the averaged response and consequently disable the originally designed SD degradation tracking algorithms. In this report, a model based on geometric factors and design parameters is developed to simulate the SDSM sun view response. It is shown that the ripples are induced by erroneous design parameters and incorrect installation of the involved optical elements. The model could be used to improve the MODIS SD calibration and to provide helpful information for the design of future remote sensing systems.**

***Index Terms*—Modeling, Moderate Resolution Imaging Spectroradiometer (MODIS), screen, solar diffuser (SD), Solar Diffuser Stability Monitor (SDSM), simulation.**

I. Introduction

THE Moderate Resolution Imaging Spectroradiometer (MODIS) is one of the key instruments for the National Aeronautics and Space Administration's (NASA) Earth Observing System (EOS) [1]–[3]. The MODIS ProtoFlight Model (PFM) onboard the Terra spacecraft and Flight Model 1 (FM1) onboard the Aqua spacecraft were launched on December 18, 1999 and May 4, 2002, respectively [4]. MODIS has 36 spectral bands providing spatial resolutions of 250 m for bands 1–2, 500 m for bands 3–7, and 1000 m for bands 8–36 at nadir. Among the bands, 20 are reflective solar bands (RSBs), and 16 are thermal emissive bands (TEBs). The RSBs cover the wavelength range from 0.4 to 2.1 μm [visible (VIS), near-infrared (NIR), and shortwave infrared (SWIR)] and are calibrated on-orbit through the use of an onboard solar diffuser (SD) panel (made of Spectralon), the Moon, and an onboard Spectro-Radiometric Calibration Assembly (SRCA) [5]–[8]. The TEBs cover the wavelength range from 3.7 to 14.1 μm and are calibrated on-orbit through an onboard blackbody (BB) [6], [9]. The MODIS two-sided scan mirror samples the SD, BB, SRCA, space view (SV), and the Earth view continuously with a scan period of 1.477 s and a swath of 10 km (nadir) along track $\times$ 2330 km cross track.

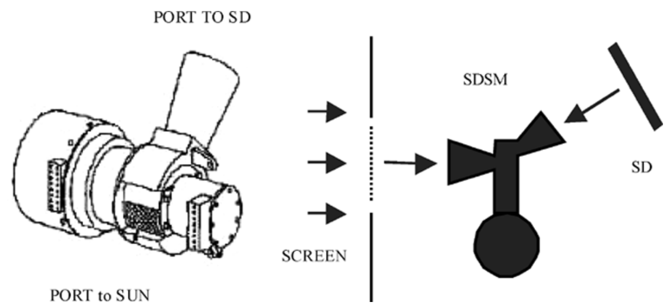

Fig. 1. SDSM (Left) Outside look. (Right) Calibration schematic.

MODIS has an onboard Solar Diffuser Stability Monitor (SDSM) designed to track changes in the SD reflectance as described by the bidirectional reflectance factor (BRF), which is essential for the SD calibration [5]. The SDSM consists of a solar integrating sphere (SIS) with a single input aperture and nine filtered detectors. Each of the detectors has a narrow spectral bandpass. The nine discrete wavelengths of the SDSM are distributed in the range from 0.41 to 0.94 μm. The SDSM views a dark scene, direct sunlight, and illumination from the SD alternately via a three-position fold mirror during a SD calibration. The direct sunlight is attenuated via a 1.44% transmission screen to avoid saturation of the detectors. Fig. 1 shows an illustration and a schematic diagram of the SDSM. If the SD reflectance degrades uniformly in all incident directions, the SD reflectance degradation can be derived by trending the ratio of the background-subtracted and solar-angle corrected SDSM sun and SD view responses.

Both the SDSM sun and SD view responses depend on the solar angle of incidence since the solar radiance reaching the SDSM SIS is a function of this angle. The effect of the solar angles must be corrected in the trending of the ratio of the two responses to derive the SD degradation. The dependence of the SDSM SD view response on the solar angle can be described using the product of $\cos(\theta_{\mathrm{SD}})$, where θ_{SD} is the angle between the incident sunlight and the normal to the SD plane, and a relative BRF, which can be derived using data from on-orbit yaw maneuvers [10]. The dependence of the SDSM sun view response on the solar angles may also be derived from the yaw maneuver data if the response is a smooth function of the solar angles. However, the on-orbit observations have shown serious ripples in the SDSM sun view response [11]. Since the ripples are as large as 10% of the averaged SDSM sun view response,

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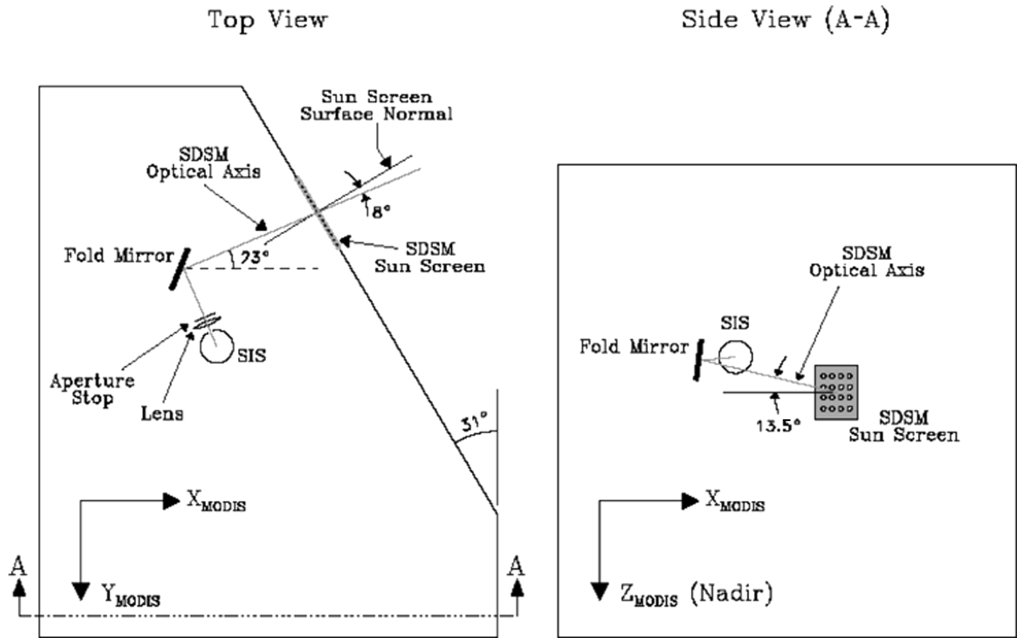

Fig. 2. SDSM sun view optical system. (Left) Top view. (Right) Side view.

a simple smooth function cannot be used to fit the measured response and to derive an accurate smooth function that describes the solar angle dependence of the SDSM sun view response. Because of this, an alternate approach is currently used to eliminate the effect of solar angles on the SDSM sun view response in the SDSM SD degradation trending [5], [6].

In this paper, we develop a model based on geometric factors and design parameters of the SDSM to simulate the SDSM sun view response. It is shown that if all these factors and parameters are matched and the components are properly aligned, the SDSM sun view response should be smooth. It is also shown that any mismatched factor or parameter can induce ripples and that the patterns of the induced ripples vary for different parameters. The on-orbit SDSM sun view data from the yaw maneuvers has been used to fit the SDSM sun view factors and parameters for both PFM and FM1. This model explains the observed ripples very well. The fitted results also indicate that the attenuation screen may not be properly aligned and that the aperture in front of the SIS was not installed correctly [12]. This model will be applied to improve the MODIS calibration and characterization. It also has the potential to help design future remote sensors.

II. Modeling

The SDSM sun view optical system consists of a solar integrating sphere (SIS) with nine filtered detectors distributed circularly inside, a lens, a square aperture stop (SAS), a fold mirror, and a sun view screen (SVS) attached to the SDSM sun view port (SVP). Only the sunlight passing through the SAS can reach the SIS, and the lens guarantees that all of the sunlight within the SAS completely reaches the SIS. Thus, the SDSM sun view response is proportional to the sunlight passing through the SAS. Fig. 2 shows the top view and the side view of the system with reference to the MODIS coordinate system.

V. Conclusion

A model based on geometric optics and MODIS SDSM design parameters was developed to simulate the MODIS SDSM sun view response. It is shown that the SDSM sun view response is a smooth function of incident angles of sunlight if the geometric parameters of the SDSM sun view optical system match certain relationships. The effects of mismatching the geometric parameters are illustrated. The model is applied to fit on-orbit SDSM sun view data from the yaw maneuvers for both Terra and Aqua SDSM. With fitted parameters, the model can explain the observed ripples very well. It is shown from the fitted parameters that the attenuation screen may not be well aligned and the Stop Aperture in front of the SDSM SIS was not installed correctly. The model will be applied to improve the MODIS SD calibration and can be used to provide useful information for the design of future remote sensing systems.